



***Test Method 1019
(Total Ionizing Dose)
Its time for 1019.10***

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About this Presentation

The SAE CE-12 RHA Users Subcommittee, and JEDEC JC13.4 Committee are in the early stages of a major revision of MIL-STD-883J Test Method 1019.9: we hope the eventual outcome of this process will become Test Method 1019.10.

The material presented today is preliminary. None of the authors, or their companies consider these suggestions as anything but material for discussion.

After a final draft is prepared, it will be widely reviewed, and community consensus achieved before submittal to DLA.

Outline



- Introduction
- A History of Test Method 1019
- An Introduction to revision in development
- Conclusions

Background

TM 1019 was established in 1978

- MIL-STD-883 Revision K, Test Method 1019.9
 - *IONIZING RADIATION (TOTAL DOSE) TEST PROCEDURE*
 - *Arguably the most recognized Radiation Test Method in the World*
 - *Specified in every DLA RHA Standard Microcircuit Drawing*
- Original 1019 released in MIL-STD-883 Rev B Notice 1 in July 1978
 - *Current format established in 1019.4, November 1991*
 - *ELDRS (Condition D) was added in 1019.6, March 2003*
 - *1019.9, June 2013, added cryogenic testing, check for bias conditions*
- Format unchanged for over 28 years
 - *Difficult to follow, multiple interpretations possible*
 - *Reflects R&D environment that dictated most changes*
 - *Not suitable for production RLAT*
- ESA 22900 TID TM is often simpler, but has differences
 - *Desire maximum compatibility between TM's*
- Rewrite to make the method support production RLAT
 - *ELDRS and Annealing are among major issues to resolve*

How to modernize a complex document with fewest unintended consequences?

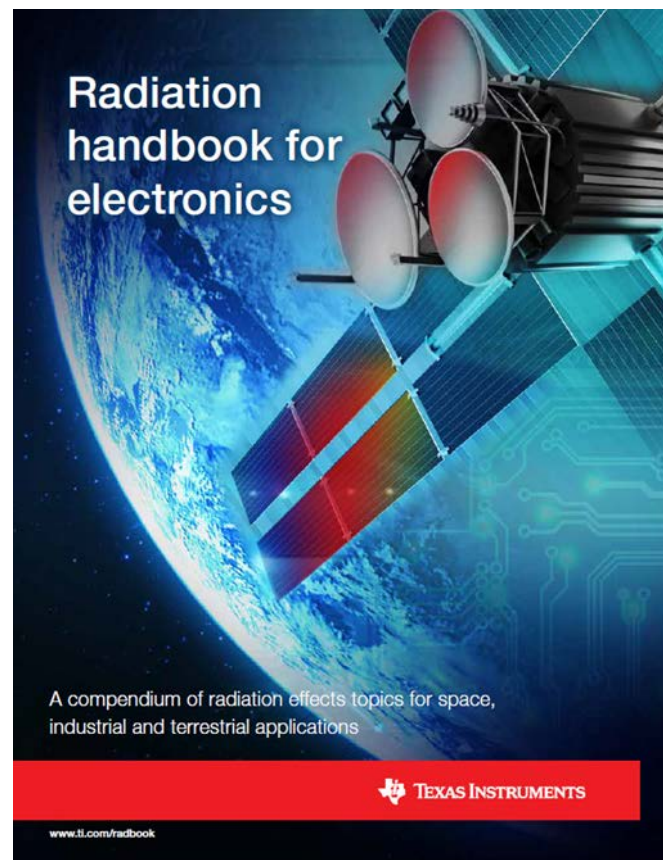


A Brief History of TM 1019

Based on a presentation by Kirby Kruckmeyer of Texas Instruments at May 2019 SAE CE12 RHA Users Subcommittee

History of MIL-STD-883 TM1019

- Presentation taken from TI's Radiation Handbook for Electronics
 - *ti.com/radbook*
- Pulled together by going through each rev of TM1019
- Researched references used for changes
- Based on own knowledge going back to 2004
 - *Many thanks to Tom Turflinger for providing document with all revs. of the MIL-STD-883 radiation test methods*





A Short Form History

- 1019 MIL-STD-883B Notice 1: Aug 1977 (B)/July 1978 (N1)
- 1019.1/883B Notice 3: Nov 1980: added in situ vs. remote requirements
- 1019.2/883B: Aug 1983 removed ASTM 567; added electron beam requirements
- 1019.3/883C Notice 1: May 1987 changed in situ to in flux; added bias board requirement: shielding and maintenance; removed requirement for testing at 3 levels
- 1019.4/883D: Nov 1991 major rewrite (looks the same as today); added MAAT and TDE; dropped electron beam source; added Pb/Al container; changed dose rate to 50 to 300 rad/s; added dose rate exemptions for application; added flow chart
- 1019.4/883D Notice3: March 1995 added bipolar/BiCMOS low dose rate warning; dose rate conditions A, B and C
- 1019.5/883E Notice 1: Dec 1997 added Extended room temp anneal test; emphasized doing lower dose rates for bipolar/BiCMOS; added burn-in requirement; gave test windows its own section, moving MAAT to section 3.11
- 1019.6/883E Notice 5: March 2003 added “ELDRS” and test requirements: 10 mrad/s with 1.5X overtest or >10 mrad/s with 2X overtest or elevated temp test; BiCMOS to be tested at both LDR and HDR; added conditions D and E; increased test window to 72 hours for condition D; added ELDRS flowchart
- 1019.7/883G: Feb 2006 added the ELDRS characterization and RLAT requirements for parts with ELDRS; elevated temp test removed, replaced with accelerated tests may be used if characterized
- 1019.8/883H: Feb 2010 added dry ice; added formula for test window based on rad exposure time
- 1019.9/883J: June 2013 added cryo testing; added requirement that bias board conditions are checked

MIL-STD-883 TM1019



- TM1019 is not a one size fits all test method
- It has evolved over the years as new effects on different technologies were discovered
- It is pragmatic
 - *It is flexible for different technologies and environments*
 - CMOS and bipolar have different TID responses
 - Different application environments have different requirements
 - Not always practical to test for every possible application; test for the target application
 - *It is realistic and flexible about testing limitations*
 - Not everyone owns a radiation source
 - HDR test capacity much greater than LDR
 - LDR takes a long time; could impact schedules
 - Irradiation can be expensive; especially LDR
 - It is not just for suppliers; it is also for upscreeners and users
- It could use a rewrite
 - *It has been stitched together over the years*
 - *It can be hard to follow*
 - *Some items are obsolete and should be removed*

Released in 1978



- TID testing with Co-60 or electron beam source
 - *Electron beam source dropped in the 1980s*
- Dose rate: 1.66 rad(Si)/s and 2,500 rad(Si)/s
 - *Tightened to 50 rad(Si)/s and 300 rad(Si)/s in the early 1990s*
 - *At the same time, option to test CMOS parts at LDR for LDR environments added*
 - Recognized that HDR was worst case for CMOS and HDR testing was precluding CMOS products for space applications
 - *Other dose rate options added later*
 - For environment flexibility as new effects are discovered
 - *ELDRS testing added in 2003*
 - Changed to ELDRS characterization in 2006

Standard total ionizing dose (TID) test



- Electrically test critical parameters of device under test (DUT)
- Bias part in an operating condition
 - *Agreed by parties to the test or worst case conditions*
- Irradiate DUT at HDR
- Remove from source and bias board
- Repeat electrical test and evaluate
- Sample size specified in MIL-STD-883 TM5004 or MIL-PRF-38535 Appendix C
 - *Used to be different but now the same*
 - *Same for qualification and radiation lot acceptance testing (RLAT)*
 - *Either wafer level or wafer lot level*
 - *Wafer level: 4 units per wafer; 2 units per wafer if more than 4000 transistors*
 - *Wafer lot level: 22 units per wafer lot (no specification on how many wafers)*

Summary of tests and dose rates



| Test | Product type | Purpose |
|-------------------------|---|---|
| HDR | Without enhanced low-dose-rate sensitivity (ELDRS) or time-dependent effects (TDEs) | Standard test for RLAT |
| MAAT | With MOS elements | Determine if the technology has TDEs |
| Room-temperature anneal | Fails HDR | Determine if product could be qualified for LDR testing |
| ELDRS characterization | With bipolar linear elements | Determine if the product has ELDRS |
| LDR | Without ELDRS | Alternative to HDR testing for RLAT |
| LDR + 1.5x overtest | With ELDRS | RLAT |
| Accelerated ELDRS | With bipolar linear elements | Alternative RLAT verified through characterization |

| Condition | Dose rate | Use |
|-----------|------------------|---|
| A | 50-300 krad | CMOS and devices that do not have ELDRS |
| B | <50 rad/s | MOS devices, as agreed to by parties to the test |
| C | Any | As agreed to by parties to the test |
| D | ≤ 10 mrad/s | RLAT for devices with ELDRS and alternative for devices without ELDRS |
| E | >10 mrad/s | Accelerated tests verified through characterization |

MOS accelerated anneal test (MAAT) or Rebound



- **Purpose: To determine if part has time dependent effects (TDE)**
 - *also known as rebound test*
 - *added in the 1980s*
- In the 1980s, some MOS products continued to degrade after being removed from radiation source
 - *Viewed as a sensitivity to low dose rates (LDR) not seen at high dose rate testing (HDR)*
 - *Time dependent effects (TDE)*
- MAAT test added for all products with MOS structures
 - *Not just CMOS but all MOS structures (bipolar products with caps)*

Test Method

Irradiate DUT to rated dose and test

Irradiate DUT an additional 50%

do not test

While biased, bake DUT at 100°C for one week

Test

If DUT degrades more, MAAT must be done at RLAT

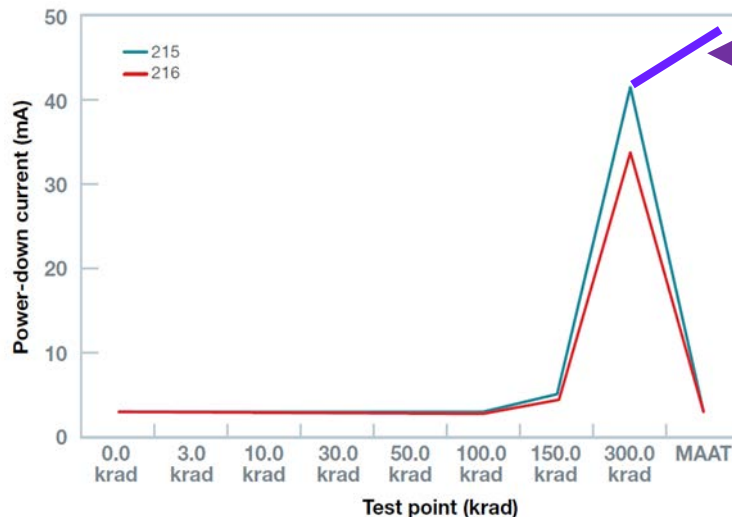
Notes

There is no test window after bake

Correlated well on some MOS technologies in the 1980s

MAAT Today

- TI performs MAAT test on all new technologies because it is required
- No products or technologies have failed MAAT
- In fact, products return to pre irradiation state after MAAT



Rebound would look like this!

Power down current for the
ADC12D1600QML-SP 1.6 GSPS 12b ADC
CMOS9X 180 nm CMOS

Extended room temperature anneal test

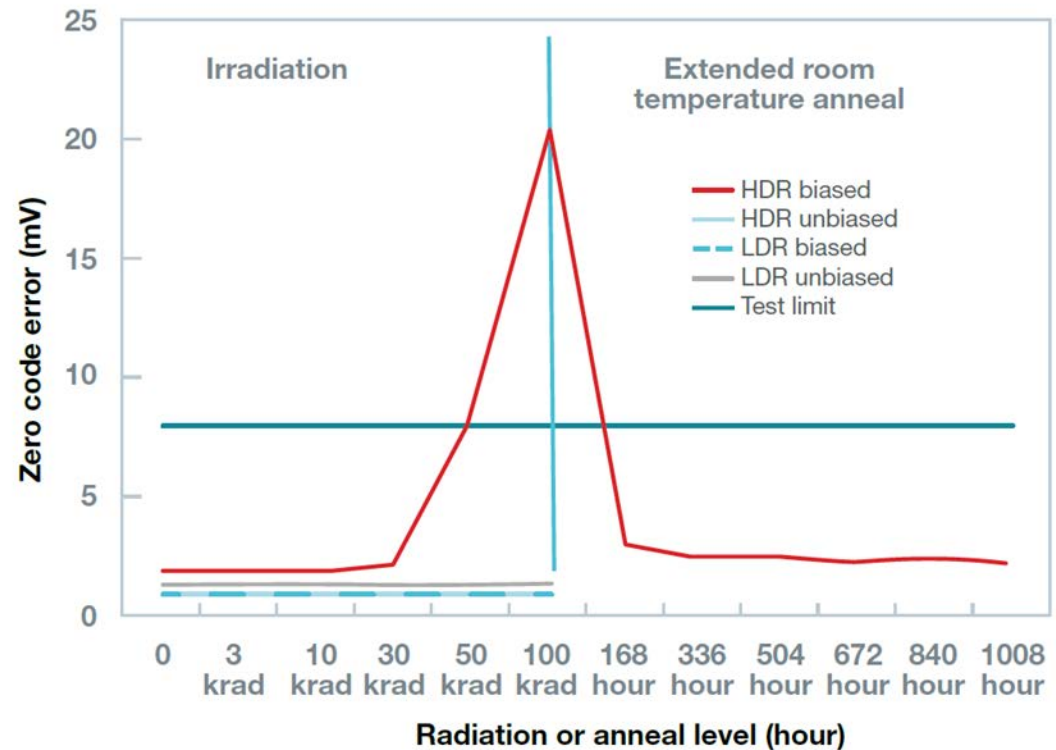


- **Purpose: To simulate LDR testing using an HDR source for products that fail HDR but are less sensitive at LDR**
 - *Added in 1997*
- On some products (especially CMOS) HDR is worst case and testing at HDR is overly conservative for LDR environments
- This test can be done on any type of product (not just CMOS)
- Test method
 - Irradiate DUT while biased to rated dose
 - Test
 - If DUT fails parametrically but still functional, product is eligible for test
 - Return DUT to bias boards and power up outside of radiation source at room temp
 - Periodically test DUT to determine if it has recovered
 - Once part has recovered determine max allowable dose rate environment
 - Divide rated dose by time it took DUT to recover

Extended room temperature test validation



- TI validated test method on some newer technologies by comparing test results to LDR testing
 - 350 nm 3.3V and 5V
 - 180 nm 1.8V
 - 180 nm 3.3V
- Extended room temp test **more conservative than LDR testing**

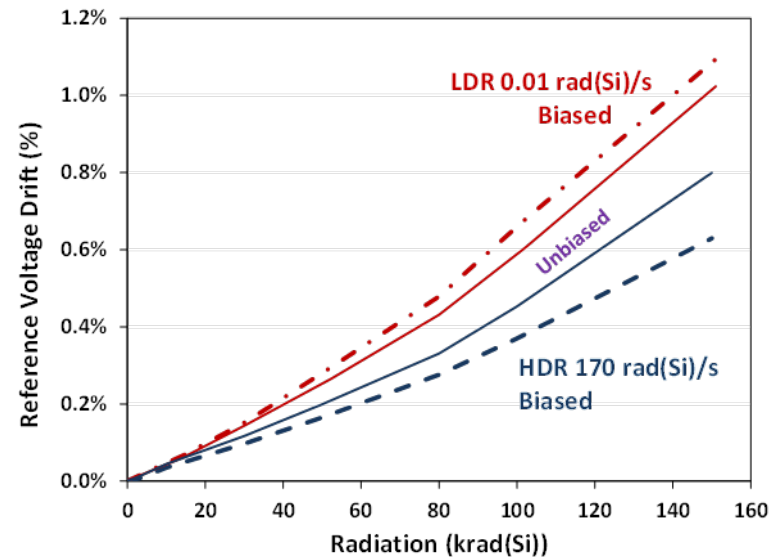


DAC121S101QML-SP 12b precision DAC

Enhanced low dose rate sensitivity (ELDRS)



- In the 1990s, it was found that some bipolar parts degrade worse at LDR than at HDR for the same TID level
- At LDR some products degrade worse when unbiased during irradiation than when biased
- As far as space applications are concerned, the standard TID test is an accelerated test
 - *It takes less than 30 minutes to reach 100 krad when testing at 300 rad/s*
- ELDRS Characterization vs RLAT
 - *Ongoing issue to resolve*





Test Method 1019.9 Revision Discussion

Based on a presentation by Nick van Vonno of
Renesas/Intersil at the May 2019 SAE CE12 RHA Users
Subcommittee

MIL-STD-883 Test Method 1019 revision: Why now?



- Revision was attempted in 2013
- Very little interest in the community; project quickly shelved.
- 2019, Discussions in 2018 suggested new attitude
 - *The current climate is thoroughly different.*
 - *Markets are fracturing; commercial space and milsat cost pressures are driving requirements and ASP's down quickly.*
- Understanding of dose rate effects has matured.

MIL-STD-883 TM 1019 revision: proposed changes



- The May 2019 concept version of the proposed TM1019 revision is baselined around a low dose rate of 0.010 rad(Si)/s
 - *as being representative of the great majority of space applications.*
- An increasingly accepted viewpoint : ‘High dose rate’ at 50 – 300 rad(Si)/s is an accelerated test, and ‘low dose rate sensitivity’ is an indication of nonlinearity in the acceleration factors of this test.’
- Significant traction seen for LDR *and* HDR RLAT models
 - *some traction for LDR-only RLAT,*
 - *introduction of upscreened plastic-encapsulated parts,*
 - *plastic versions of RHA parts,*



MIL-STD-883 TM 1019 revision:

the LDR dose rate range

- Low dose rate is defined as a dose rate less than or equal to 0.100 rad(Si)/s:
 - *I'm somewhat conflicted on the LDR limit, but I had to limit the range, and this dose rate accommodates the ESA 0.100 rad(Si)/s limit.*
 - *Maximum dose rate will be significant discussion point*
- There have been concerns about testing in the 0.100 rad(Si)/s to 50 rad(Si)/s range, but in this model it is an accelerated test anyway.
- The present HDR standard range of 50 – 300 rad(Si)/s retained:
 - *Infrastructure, procedures, irradiators, irradiator fixturing*

MIL-STD-883 TM 1019 revision: anneals



- Accelerated annealing test retained:
 - *It evaluates time dependent effects (TDE) or rebound which are a valid concern in CMOS technologies.*
- Room temperature annealing test retained:
 - *It evaluates possible overly conservative results introduced by high dose rate testing of MOS devices, which would likely show real-time annealing in the low dose rate space environment.*
 - *Consider it basically a salvage procedure, but have no objections to its inclusion.*

MIL-STD-883 TM 1019 revision: top level contents



Outline

1. Purpose.
2. Definitions.
3. Test plan.
4. Apparatus.
- 5.** (applicable to all conditions)
6. Test report
7. Summary.

Appendix: Guidelines

Section 5 Details

- | | |
|------|---|
| 5.0 | General procedures. |
| 5.1 | Dosimetry measurements. |
| 5.2 | Temperature requirements. |
| 5.3 | Sample selection and handling. |
| 5.4 | Electrical performance measurements. |
| 5.5 | In-flux and out of flux electrical testing. |
| 5.6 | Irradiation bias and loading conditions. |
| 5.7 | Irradiation. |
| 5.8 | Post-irradiation procedure. |
| 5.9 | Off-site electrical testing. |
| 5.10 | Dose rate. |
| 5.11 | Correlation study to determine if an optional test adequately bounds the standard low dose rate response of the part. |
| 5.12 | Accelerated annealing test. |
| 5.13 | Extended room temperature biased anneal test. |
| 5.14 | Cryogenic temperature irradiation. |



A quick comparison to ESA TM 22900

Better commonality is desired, but not a stated goal

- Issue 4, dated October 2010 is current ESA method
 - *Original Issue 1995*
- Space oriented, and one (LDR) test flow
 - *Limited use of 100 mrad/s is controversial*

| | TM 1019 | No. 22900 |
|---------------------------|--|---|
| Scope | Multiple environments | Space only |
| Test-flow options | Options based on technology and radiation environment | One test flow |
| Room-temperature anneal | Use on select products that fail an HDR for LDR environments | Done on all products as part of the test flow |
| ELDRS characterization | On linear devices only with bipolar elements | On all devices with bipolar transistors |
| ELDRS dose rate | 10 mrad/s | 10 mrad/s to 100 mrad/s |
| HDR | 50 rad/s to 300 rad/s | 0.1 rad/s to 50 rad/s |
| 1.5x overtest requirement | On products with ELDRS | No |

Summary

TM1019.10 must be both cost effective and technically correct

- TM1019.9 is widely used, but difficult for both vendors and users
 - *Inclusion of 2 annealing techniques and ELDRS (actually LDR test) confusing*
 - *There are multiple possible ways to test for same effects*
- Current draft suggests making LDR test the primary test method
 - *Recognize HDR as an accelerated test method*
 - *Retain both annealing techniques for HDR*
 - *Retain Cryogenic irradiations, and dry ice shipping for remote test*
- Primary goal is a method that supports efficient RLAT testing
 - *Characterization and R&D test needs must be addressed*
 - A guideline or companion document one possible solution
- Because of wide-spread use, change is difficult
 - *Unintended consequences and unexpected costs must be minimized*
 - *One possibility is to develop a new test method*
 - Allow long overlap period so retest only for method is avoided
- Programmatic changes require an improved Test Method
- Finally, desire increased commonality with ESA 22900

Looking for those few with knowledge and interest to help this change